# SIMULATION FOR OPTIMAL UTILIZATION OF HUMAN RESOURCES IN SURGICAL INSTRUMENTS DISTRIBUTION IN HOSPITALS

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## ABSTRACT

Hospitals seek ways to streamline the process of internal distribution of surgical instruments and optimize the use of human resources involved in the process. Using simulation models, this paper attempts to assess the utilization of human resources involved in the process of surgical instruments distribution within a Singaporean hospital and provide a recommendation for more optimal utilization of human resources in the process. The results will prove helpful to those who consider streamlining the process of surgical instruments distribution in hospitals and other similar processes.

**KEYWORDS**: Hospital, simulation, internal distribution, human resource utilization

## INTRODUCTION

With escalating healthcare costs, hospitals seek ways to contain operating costs and at the same time provide quality healthcare service. Hospitals have traditionally emphasized on breakthroughs in technology and procedures for surgical care. As competition among hospitals continues to intensify, however, patients often perceive little difference in such technology and procedures used by different hospitals. Further, the facility for surgical care, which is a critical part of any hospital that provides surgical care service, consumes multitudes of resources, but it also generates significant revenue if managed properly. For this reason as well as others, hospitals seek ways to streamline the process of surgical care and optimize the utilization of resources involved in the process. Given the shortage and rising costs of human resources in healthcare, efficient allocation and utilization of human resources can help hospitals contain costs, improve efficiency, and stay competitive in the marketplace.

Using simulation models, this paper attempted to assess the utilization of human resources involved in the process of surgical instruments distribution in a Singaporean hospital (referred to as 'the Hospital' hereafter, for anonymity and brevity) and to provide a recommendation for more optimal utilization of human resources in the process. The process of internal distribution of surgical instruments in the Hospital involves personnel in the Theatre Sterile Supply Unit (TSSU) where surgical instruments are decontaminated, processed, sterilized, and stored, as well as personnel in the Operating Theatre (OT) rooms where operations take place. The results will prove helpful to those who consider streamlining the process of internal distribution of surgical instruments in hospitals and other similar processes.

## STUDY BACKGROUND

### *Distribution Systems in Hospitals*

For healthcare services, hospitals need various products and services such as medical consumables, pharmaceuticals, catering and food, laundry cleaning, waste management and disposal, homecare products, information technology, vehicle fleet management, and general research supplies (Gattorna, 1998). Also, various methods and systems have been proposed and examined for efficient supply and distribution of such products and services to hospitals and within hospitals.

Kim et al (1993) identified three types of material management systems in the health care industry, including conventional, just-in-time, and stockless systems, and empirically tested the systems' significance on the total inventory cost and service quality improvement. Okogbaa et al (1994) analyzed the material handling system at a 900-bed hospital, using simulation models. Heinbuch (1995) highlighted the value of just-in-time inventory management system for materials management in clinical areas of hospitals. Huang (1998) classified the types of material management systems within Taiwanese hospitals, using a fuzzy clustering method. He compared inventory turnover rates and fill rates among those different types of systems. He recommended that Taiwanese hospitals should pay more attention to improving their inventory productivity. He pointed out that the failure of accurate record keeping is the source of unnecessary performance problems. Clare et al (2000) studied how total quality management principles improved the healthcare sector in Singapore.

The choice of distribution systems for healthcare materials depends on the needs of each hospital, the services that the hospital or facility provides, and its size, physical design, age and financial resources and goals. Since these factors change over time, hospital management must reevaluate and modify their distribution systems periodically to ensure optimum efficiency and cost effectiveness.

### *Internal Supply of Surgical Instruments in the Hospital*

TSSU in the Hospital sterilizes about 6,000 to 7,000 surgical instruments, which are supplied to 67 OT rooms. A senior nursing officer leads TSSU. Under her supervision are 19 nurses, 19 healthcare assistants, 2 clerks, and 2 nurse managers. TSSU operates from 7:00AM to 9:00PM daily. TSSU nurses and healthcare assistants work in two shifts on a weekday and four shifts on Saturday and Sunday. TSSU is composed of four major areas based upon the tasks that it performs: 1) the decontamination area where used or contaminated surgical instruments are cleaned and rendered safe to handle; 2) the processing area where clean or decontaminated surgical instruments are inspected, assembled, and packaged; 3) the sterilization area where any microorganisms found in packages of surgical instruments are destroyed; and 4) the storage area where sterile packages of surgical instruments are stored in a controlled environment with respect to temperature, humidity, ventilation, and so on.

Figure 1 shows the process of normal order and distribution of surgical instruments. An OT staff first fills up a request form for surgical instruments needed for an operation before the day of the operation, and sends the request form to TSSU via an automatic lift (dump waiter). TSSU staff collects request forms from the dump waiter between 2:00PM and 5:00PM while most requests for surgical instruments are made. TSSU nurses pack surgical instruments on 'clean' trolleys. At 8:30PM every night, each 'clean' trolley containing surgical instruments is delivered to the holding area of the respective OT room for use on the following day, and the surgical instruments issued are recorded on the inventory control system in TSSU. On the day of the operation, an OT staff takes over the 'clean' trolley and delivers it to the OT room for use in the operation. Upon completion of the operation, unused surgical instruments in the 'clean' trolley are taken by a TSSU staff and brought back to TSSU. OT nurses put surgical instruments that have been used or contaminated during the operation in a "dirty" trolley, which is also taken by a TSSU staff and brought to TSSU. An OT nurse fills up the form for return of used surgical instruments and places it on the 'dirty' trolley. Figure 2 shows the floor layout of OT rooms. In TSSU, a staff unloads surgical instruments in both trolleys and updates data in the inventory control system. Then, used surgical instruments are sent to the decontamination area for cleaning.

In addition to normal orders, TSSU has to deal with ad hoc orders in emergency cases. For example, when there is a last-minute adjustment to the surgical instruments already ordered for an operation or when surgical instruments are needed immediately for an emergent operation, OT nurses can take surgical instruments required for the operation without giving a prior notice to TSSU. Ad hoc orders for surgical instruments are most made for emergency surgeries (38 percent), followed by neuro (22 percent), cardio thoracic (12 percent), general (10 percent), orthopedic (6 percent), ear/nose/throat (6 percent), plastic (4 percent), colorectal (1 percent), and obstetric and gynecology (1 percent) surgeries. It is very difficult, if not impossible, to know in advance what types of and how many of surgical instruments are needed for an emergency surgery, due to the uncertain nature of the surgery. Also, surgeries in some disciplines, e.g., neuro surgeries, tend to require additional surgical instruments at the last minute more frequently than surgeries in other disciplines.

Ad hoc orders for surgical instruments pose several problems to TSSU. OT nurses often do not fill up request forms properly, since they usually rush to get surgical instruments in emergency cases. As a result, data on surgical instruments taken out by OT nurses are often not recorded correctly in the inventory control system of TSSU. Also, used or contaminated surgical instruments after operations are often not properly brought back to TSSU. OT nurses sometimes do not check thoroughly the types and quantities of surgical instruments after operations. Taken together, these problems cause inconsistency of the records of surgical instruments taken out from and brought back to TSSU in the inventory control system. Moreover, OT nurses waste their time in going to TSSU and getting surgical instruments, as they would be better off to spend more time in their primary tasks in OT rooms.

As an effort to solve these problems, TSSU considers adopting a new process of ad hoc orders and distribution. The new process of ad hoc orders and distribution includes the following steps: 1) orders are requested by OT nurses; 2) orders are retrieved by TSSU staff; 3) packages of surgical instruments are prepared by TSSU staff for delivery to OT rooms; 4) packages of surgical instruments are delivered to OT rooms by delivery persons; and 5) data in the inventory control system is updated by TSSU staff. A key aspect of the new process is that OT nurses no longer go to TSSU to get surgical instruments by themselves, and instead, additional workers will be hired and they will deliver surgical instruments to OT rooms. Using simulation models, we assess the efficiency of this new process of ad hoc orders and distribution in terms of the utilization of additional workers to be hired and the states of surgical instruments in the process.

Figure 1. Process of normal order and distribution of surgical instruments

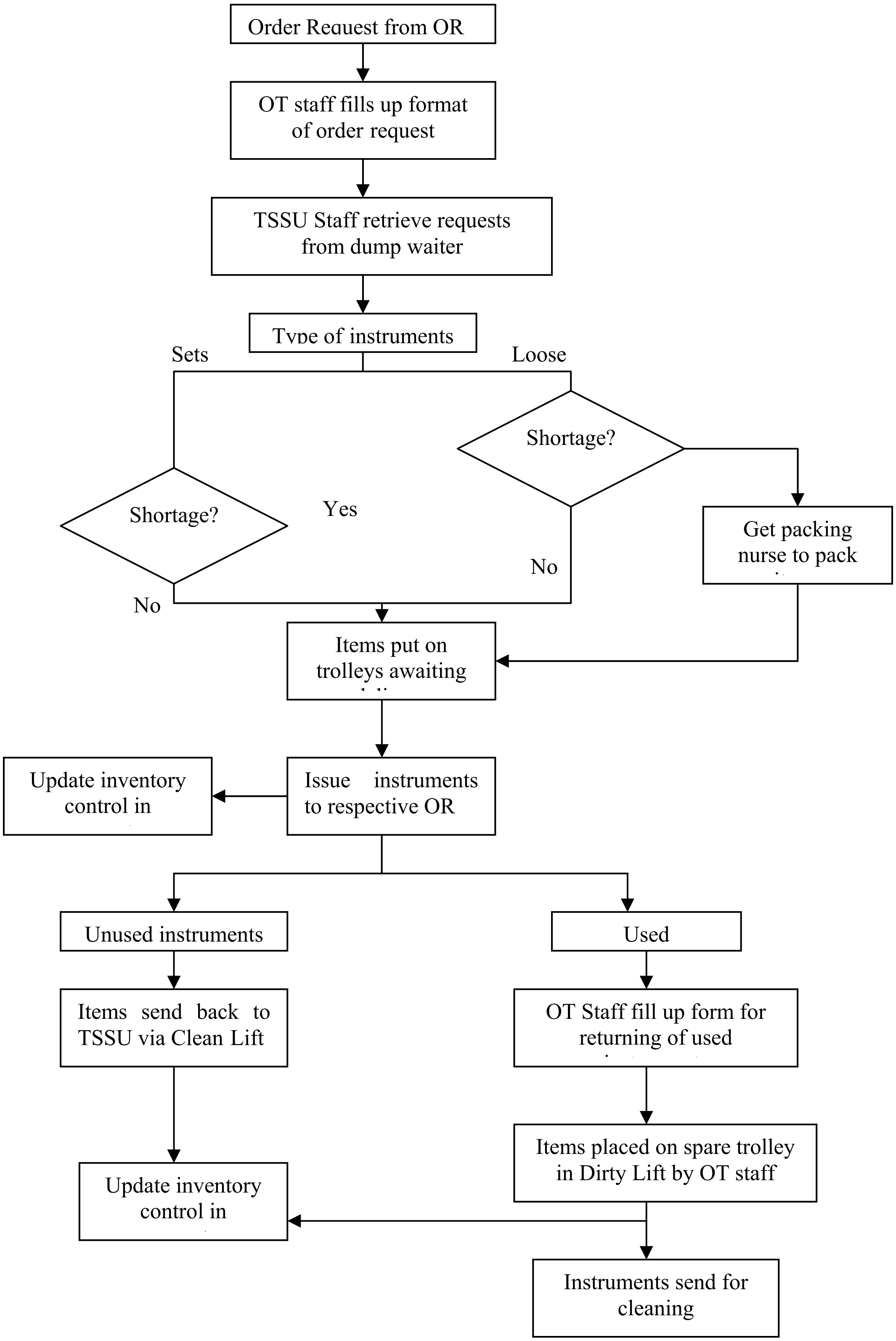
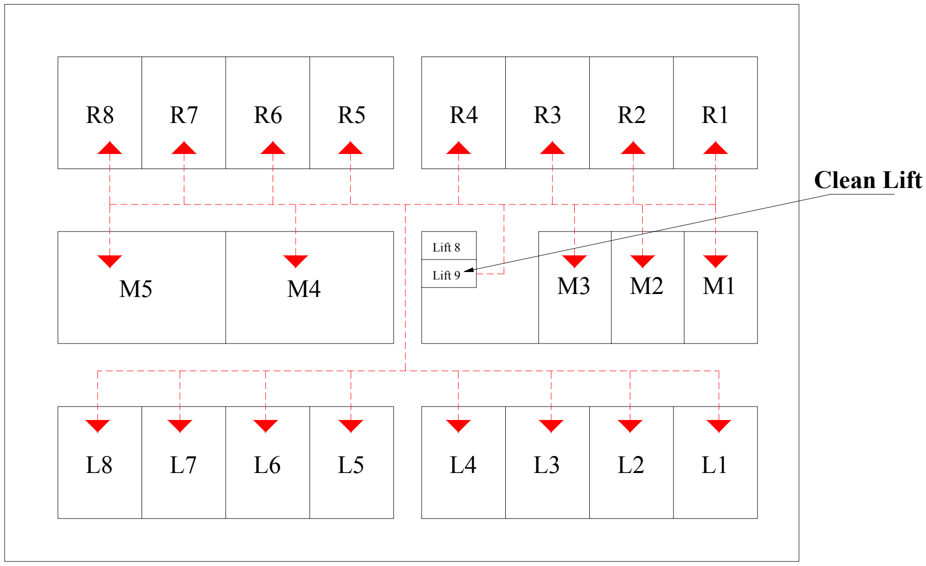


Figure 2. Floor layout of OT rooms



## SIMULATION MODELS AND RESULTS

### *Data and Assumptions*

The main objective of the simulation is to find out and recommend the optimal number of additional workers to be hired for a more efficient process of ad hoc orders and distribution of surgical instruments. Data was collected on the following factors: 1) the numbers of loose surgical instruments and sets of surgical instruments that are issued responding to normal and ad hoc orders, 2) the number of trips made by OT staff to TSSU to get surgical instruments, 3) the numbers of loose surgical instruments and sets of surgical instruments of which records are missing in the decontamination area, and 4) the numbers of surgical instruments and sets of surgical instruments that are sent to the decontamination area for cleaning after operations. Data was collected for orders from 21 OT rooms over a period of two weeks in December 2003. We also made the following assumptions in the simulation: 1) there is no distinction between loose surgical instrument and sets of surgical instruments, and so, both are grouped under a common category as surgical items; 2) surgeons can switch OT rooms for a given type of surgery, and so, OT room numbers do not matter; and 3) the inter-arrival time between ad hoc orders is 10 minutes. Table 1 shows the assignment of the 21 OT rooms by surgical discipline and the average travel time from TSSU to OT rooms.

Table 1. Assignment of OT rooms by surgical discipline and average travel time from TSSU to OT rooms

| OT room number | Surgical discipline | Travel time from TSSU |
|---|---|---|
| R1 | Emergency | 6 |
| R2 | Emergency | 6 |
| R3 | General | 5 |
| R4 | General | 5 |
| R5 | Cardio thoracic | 5 |
| R6 | Ear/nose/throat | 6 |
| R7 | Plastic | 6 |
| R8 | Cardio thoracic | 7 |
| M1 | Orthopedic | 5 |
| M2 | Orthopedic | 5 |
| M3 | General | 4 |
| M4 | Cardio thoracic | 4 |
| M5 | Cardio thoracic | 6 |
| L1 | Orthopedic | 5 |
| L2 | Orthopedic | 5 |
| L3 | General | 4 |
| L4 | General | 4 |
| L5 | Colorectal | 4 |
| L6 | Obstetric and gynecology | 4 |
| L7 | Obstetric and gynecology | 6 |
| L8 | Ear/nose/throat | 6 |

Note: Travel times from TSSU to OT rooms are normally distributed with mean of 5.14 and variance of 0.91.

*Parameters*

In the simulation, we considered the following parameters associated with the process of ad hoc orders and distribution of surgical instruments:

1) Locations: Locations represent fixed places where entities are routed for processing, storage, or some other activity. Locations may be machines, workstations, queues, waiting areas, and so on. The capacity of a location is the maximum number of entities that the location can hold at any one time. A location or resource fails to operate during downtime, and then, it is not available for use. In this simulation, TSSU desks and OT rooms are locations, and the capacity of a TSSU desk is 100 entities and the capacity of an OT room is 32 entities.
2) Entities: A process involves various entities such as parts, products, people, and so on. In this simulation, both loose surgical instruments and sets of surgical instruments are entities. The types of surgical instruments do not matter, because surgical instruments are loaded onto trolleys and the types of surgical instruments do not make any difference to those who deliver trolleys to OT rooms.
3) Resources: A resource is a person, equipment, or other device that is used for one or more of functions such as transporting entities, assisting in performing entities, assisting in performing operations on entities at locations, or performing maintenance on other resources. In this simulation, additional workers to be hired for delivery of surgical instruments to OT rooms are resources.
4) Path networks: A path network is the route taken by a resource to travel between locations. In this simulation, it is the path from TSSU to OT rooms.
5) Interfaces: If an entity is picked up or dropped off at a particular location by a resource, the location must connect to a node through a location-node interface in the path network. This parameter defines the number of location-node interfaces in the path network. In this simulation, two nodes are in existence at TSSU desks and OT rooms.
6) Processing: Processing is routing of the entities involved and operations taking place at each location that they enter. In this simulation, the process of delivery of surgical items is between the two locations: TSSU desks and OT rooms.
7) Arrival: Any time when new entities are introduced into the process is defined as an arrival. An arrival record specifies the number of new entities per arrival, frequency of arrivals, location of arrivals, time of the first arrival, and total occurrences of arrivals.

*Results*

Table 2 shows the current level of utilization of TSSU nurses and healthcare assistants in the TSSU areas. Given the recommended level of utilization of TSSU staff, which is about 70 percent, all nurses except those in the processing area are over utilized, and all healthcare assistants except those in the storage area are over utilized. This result is confirmed by the fact that most nurses and healthcare assistants in TSSU presently extend their daily working hours to handle excessive workloads. Consequently, TSSU needs to hire additional workers who will deliver surgical instruments to OT rooms.

Table 2. Utilization of Human Resources in TSSU (percentage)

| | Average | Minimum | Maximum |
|---|---|---|---|
| Decontamination – healthcare assistants, AM | 85.2 | 84.3 | 86.1 |
| Decontamination – healthcare assistants, PM | 80.9 | 79.0 | 82.5 |
| Decontamination – nurses, AM | 95.4 | 94.5 | 96.4 |
| Decontamination – nurses, PM | 94.2 | 92.7 | 95.8 |
| Processing – healthcare assistants, AM | 82.9 | 81.6 | 85.1 |
| Processing – healthcare assistants, PM | 77.6 | 75.7 | 79.3 |
| Processing – nurses, AM | 67.9 | 66.5 | 68.6 |
| Processing – nurses, PM | 61.3 | 60.0 | 62.5 |
| Storage – healthcare assistants, AM | 66.9 | 66.3 | 67.5 |
| Storage – healthcare assistants, PM | 60.9 | 60.5 | 61.6 |
| Storage – nurses, AM | 93.4 | 92.3 | 95.0 |
| Storage – nurses, PM | 93.2 | 92.7 | 93.7 |
| Sterilizing – nurses, AM | 99.3 | 98.3 | 99.8 |
| Sterilizing – nurses, PM | 98.5 | 96.8 | 99.8 |
| Healthcare assistants, Saturday PM | 93.8 | 87.3 | 96.7 |
| Healthcare assistants, Sunday AM | 91.0 | 86.6 | 98.0 |
| Healthcare assistants, Sunday PM | 95.2 | 92.4 | 98.0 |
| Nurses, Saturday PM | 96.0 | 89.6 | 100.0 |
| Nurses, Sunday AM | 94.3 | 88.8 | 99.4 |
| Nurses, Sunday PM | 92.3 | 86.8 | 94.4 |

We used the simulation software ProModel. ProModel is one of the leading simulation software programs, intending to help improve business process and support business decisions for manufacturing, healthcare and pharmaceutical industries (http://www.promodel.com). We ran five simulation scenarios of ad hoc orders and distribution, with one to five additional workers for delivery of surgical instruments from TSSU to OT rooms, respectively. Table 3 shows the utilization of additional worker(s) in the five simulation scenarios, given the same workload. As the number of additional workers increases from one to five, the utilization of additional workers decreases from about 90 percent to about 24 percent. Given the recommended level of utilization of TSSU staff, which is about 70 percent, it is suggested to hire two additional workers, who will deliver surgical instruments from TSSU to OT rooms.

Table 3. Utilization of additional workers

| Scenario | Hours scheduled | In use (%) | Travel to use (%) | Idle (%) | Utilization (%) |
|---|---|---|---|---|---|
| 1 | 2.4 | 51.25 | 47.02 | 1.74 | 98.26 |
| 2 | 3.48 | 34.73 | 32.83 | 32.44 | 67.56 |
| 3 | 4.27 | 29.46 | 21.69 | 48.85 | 51.15 |
| 4 | 6.35 | 18.79 | 15.23 | 65.98 | 34.02 |
| 5 | 8.75 | 13.36 | 10.15 | 76.49 | 23.51 |

In general, there are three states of surgical instruments in the process of distribution: 1) they are in move from TSSU to OT rooms and from OT rooms back to TSSU, 2) they are in the holding area of OT rooms, or 3) they are being used in OT rooms. We ran the five simulation scenarios on these three states of surgical instruments, and Table 4 shows the results. There is a big difference in all three states between Scenario 1 and the other scenarios. In Scenario 1 (one additional worker), surgical instruments spend as much as about 72 percent of time in the holding area, waiting to be used in OT rooms. Also, there is no big difference in all three states among the other four scenarios (two to five additional workers). Thus, it is recommended to hire two additional workers, who will deliver surgical instruments from TSSU to OT rooms. At the present level of workloads of ad hoc orders and distribution, TSSU does not need hire more than two additional workers, since the increase in utilization of workers with more than two workers is minimal. Also, it is recommended to hire workers who are less specialized and so, command a lower wage than OT nurses, since the task of delivering surgical instruments is rather simple.

Table 4. State of surgical instruments ordered

| Scenario | Being delivered | Waiting (%) | Being used (%) |
|---|---|---|---|
| 1 | 15.02 | 72.30 | 12.69 |
| 2 | 38.11 | 29.18 | 32.72 |
| 3 | 41.56 | 23.93 | 34.52 |
| 4 | 39.94 | 25.33 | 34.73 |
| 5 | 40.31 | 23.97 | 35.72 |

## CONCLUSION

We attempted to assess the utilization of TSSU staff involved in the process of orders and distribution of surgical instruments in the Hospital. The results show that TSSU staff is currently over utilized. We also ran several simulation scenarios to find out how many additional workers are needed to respond to ad hoc orders and deliver surgical instruments to OT rooms. The results recommend hiring two additional workers, preferably less skilled workers than OT nurses who currently bring surgical instruments to OT rooms by themselves on emergency cases. Taken together, these results can help streamline the process of ad hoc orders and distribution of surgical instruments and optimize the utilization of human resources in the process in the Hospital.

## REFERENCES


Clare, F. P., Chua, C., and Goh, M. "A Quality Roadmap of a Restructured Hospital," *Management Auditing Journal*, 2000, pp. 29-41.

Gattorna, J. L., *Strategic Supply Chain Alignment - Best Practice in Supply Chain Management*, Gower, 1998.

Heinbuch, S. E., "A Case of Successful Technology Transfer to Healthcare," *Journal of Management in Medicine*, 9, 1995, pp. 48-56.

Huang, F., "Hospital Material Review in Taiwan," *Hospital Material Management Quarterly*, 19, 1998, pp. 71-81.

Kim, C. G. and Schiederjans, M. J., "Empirical Comparison of Just-in-Time and Stockless Management," *Hospital Material Management Quarterly*, 14, 1993, pp. 65-75.

Okogbaa, O. G., Shell, R. L., and Clark, G. M., Modeling, Simulation and Analysis of an Automated Material Handling System," *International Journal of Physical Distribution and Logistical Management*, 24, 1994, pp. 15-32.

ProModel, (http://www.promodel.com).